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BOOK PRESERVATION TECHNOLOGIES

CONGRESS OF THE UNITED STATES OFFICE OF TECHNOLOGY ASSESSMENT

WASHINGTON, DC 20510-8025

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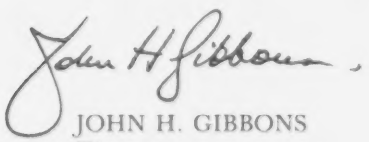
Foreword

Even in today's high-tech society, books are the principal records of human civilization. Over the centuries, books have become the most reliable and permanent records available, but, in the last century, that reliability has been threatened by the use of "modern," acidic paper that becomes brittle and unusable in a relatively short time. Books printed since 1850 are deteriorating en masse in libraries the world over. Nowhere is this problem more severe than in the U.S. Library of Congress; a major preservation program addressing it was initiated in the early 1970s. The Library's mass deacidification process is now being tested at a pilot plant, and planning is underway to design and construct a full-scale facility that could treat about 1 million books each year.

This assessment analyzes the problem of acid deterioration of books and the program underway at the Library of Congress. The program at the Library involves the chemical treatment of books in a unique and effective process that, however, also presents some new engineering and safety concerns. Because of these concerns, the House of Representatives Committee on Appropriations requested this independent review of the Library's system and other available or potential processes. OTA has evaluated the Library's process and program with a focus on effectiveness and safety, and compared it to available alternatives. OTA has also developed information and analyses useful to other major libraries in the Nation that are faced with the same problem of preserving valuable books and papers.

OTA is grateful for the assistance provided by the assessment's advisory panel, workshop participants, and other consultants, and acknowledges the full cooperation of the Library of Congress in responding to requests for information, arranging meetings with its consultants, and reviewing materials. OTA also appreciates the efforts made by the developers of other deacidification processes to make available the most up-to-date information.



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NOTE: OTA appreciates and is grateful for the valuable assistance and thoughtful critiques provided by the advisory panel members. The panel does not, however, necessarily approve, disapprove, or endorse this report. OTA assumes full responsibility for the report and the accuracy of its contents.

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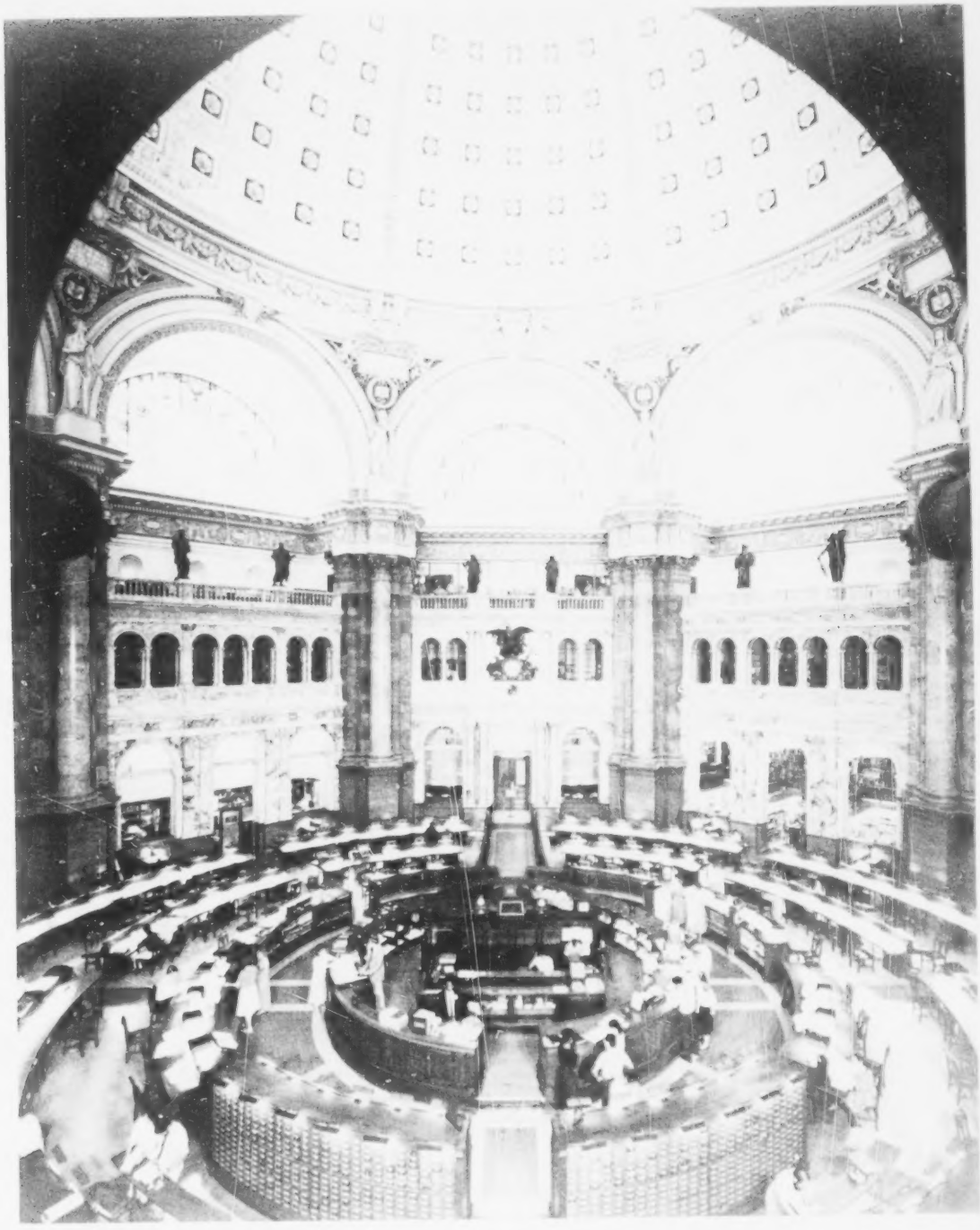


Summary

INTRODUCTION

Millions of books at the Library of Congress and other libraries around the world, published since the mid-1800s, are deteriorating so badly that they are currently, or will soon become, too fragile to handle. The paper on which these books are printed becomes brittle over time and crumbles. The primary cause of this deterioration is acid. Some chemicals used in the manufacture of paper from wood pulp stay in the paper, convert to a variety of acids and slowly destroy the strength of the paper's fibers over time. Other factors such as oxidation, varying or extreme temperature and humidity, exposure to light, air pollutants in storage areas, and high use also contribute to the destruction of the books.

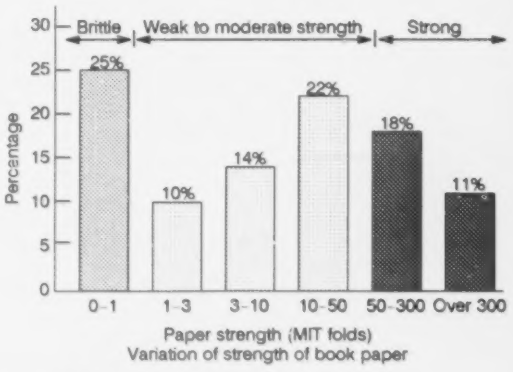
The Library of Congress has been working to solve the problem of acid paper in books since the early 1970s, developing a mass deacidification process that would inhibit the deterioration of book paper. About 25 percent of the 14 million books at the Library of Congress are too brittle for normal use. The main purpose of the Library of Congress program is to preserve and extend the life of paper materials before they reach this brittle, unusable condition. The basic strategy proposed by the Library is to deacidify all new books (about 350,000 per year) as they enter the Library. This strategy treats the most durable books first because they have a greater chance of a longer life with deacidified paper. In addition, the Library plans to treat the rest of its book collection that is not yet degraded beyond use, over a 20-year period. Approximately 80,000 books become unusable each year. The Library also intends to deacidify millions of other paper materials, such as maps, manuscripts, and sheet music, pending further testing of its process.

What Is The Library of Congress?

- The largest center for information storage in the world.
- Collections include 19 million volumes and 58 million pieces of stored data on phonograph records, motion picture reels, computer tapes, manuscripts, maps, prints, and photographs.
- Three Canons of Selection established in the 1940s to define the collections:
  —materials necessary to the Congress and to the U.S. Government officers in performance of their duties;
  —materials that express and record the life and achievements of the people of the United States; and
  —records of other societies and peoples, especially those of most immediate concern to the people of the United States.
- Less than 25 percent of the collection is in English.
- Serves five audiences:
  1. Congress—Library provides research support, policy analysis, and training through the Congressional Research Service;
  2. professional library world—Library provides cataloging and other bibliographic services and leadership on library technology;
  3. executive agencies—Library provides information resources;
  4. scholars—Library provides research collections and support; and
  5. creative world—Library protects products and preserves traditions.

SOURCE: Charles A. Goodrum and Helen W. Dalrymple, *The Library of Congress* (Boulder, CO: Westview Press, 1982), p. 337.

Library of Congress General and Law Collections Survey of Paper Strength



SOURCE: Library of Congress, January 1984.

Library of Congress Collections on Paper As of Sept. 30, 1986
(numbers rounded to nearest thousand)

	Collection	Volumes	Sheets
DEZ treatment expected	Regular books	14,046,000	
DEZ treatment planned	Manuscripts		35,522,000
	Maps		3,862,000[a]
	Sheet music		3,699,000
DEZ treatment considered	Other printed materials		6,647,000[a]
	Technical reports	1,414,000	
	Art books	348,000	
	Music manuscripts		319,000
	Prints and drawings		257,000
	Pamphlets		179,000[c]
	Popular applied graphic arts		95,000
	Posters		61,000
No DEZ[d] treatment	Rare books	594,000	
	Fine prints		95,000[b]
	Bound newspapers	40,000	

[a]Includes some volumes.
[b]Includes some portfolios.
[c]Mostly booklets.
[d]The Library's diethyl zinc (DEZ) mass deacidification process.

SOURCE: Library of Congress.

Other libraries and researchers have also worked on this problem and small-scale processes are in use. Questions have been raised about the technological effectiveness, safety, toxicology, environmental impact, and cost-effectiveness of the Library system. These questions led the House of Representatives Committee on Appropriations to request an independent review by the Office of Technology Assessment of the safety and efficacy of the Library's process and of the status of other available or potential processes. Although this assessment focuses mainly on the Library of Congress, it will hopefully assist the library community, in general, with decisions on how to cope with the acid deterioration of books.

Photo credit: Library of Congress

Brittle book from the Library of Congress' collection

ACID DETERIORATION OF PAPER

The problem of acid deterioration of library books and other paper-based assets is not new. During the 1930s a number of researchers began to study the problem more systematically, establishing a correlation between the acid content of paper and its lack of permanence (the ability of paper to maintain its durability over time). The rapid increase in the size of library collections beginning in the late 19th century has created for the libraries and other institutions a crisis of enormous proportions.

Paper can be extremely stable, maintaining its durability for centuries if taken care of properly. There are many examples of books published as far back as the 1500s that are still in fine condition. Paper permanence has slowly declined over the years, however, to the point where we are lucky if most "modern" papers, paper made since the mid-19th century, will last 50 years.

The more rapid deterioration of modern paper has been attributed to acids that accumulate in the

paper. The acids come from chemicals that are either left in the paper during the papermaking process or introduced subsequently from the environment. The acids attack the cellulose fibers that make up paper, breaking them into smaller and smaller pieces, until the paper has lost all of its durability.

The effect of acid content in paper can be devastating. In 1959, the William Barrows Laboratory, with support from the Council on Library Resources, measured the durability of books published in the United States between 1900 and 1949. A 500-book sample was taken from libraries in and around the Richmond, Virginia area where the Laboratory was located. The study determined that 39 percent of the books published between 1900 and 1939 had already become very weak; the pages would crack after moderate use and would probably become too brittle to handle at all in another 25 years. Furthermore, another 49 percent of the books had a durability less than that of newsprint, the weakest paper used for printing.

Numerous libraries have sampled their collections and found the same sobering statistics (e.g., University of California, Yale, and Stanford). Yale's study concluded that 43 percent of the libraries' 9 million books are brittle and another 44 percent have a high acid content.

The extent of the problem nationwide is staggering. The Association of Research Libraries (ARL) has estimated that 75 million books in the Nation's research libraries alone are endangered. Although many of these are still in print and can be repurchased by libraries, the ARL estimates that over the next 20 years, at least 3.3 million volumes must be transferred to another format if they are to be used.

An often-cited long-term solution to the problem of acid deterioration is to print books on acid-free paper to start with, but there are many barriers to this approach. These include economic obstacles that impede production of more acid-free paper and the fact that only a very small amount of total paper production ends up in books. Although many university publishing houses now require the use of acid-free paper, and libraries have lobbied papermakers and publishers to move in this direction, most experts agree that only 15 to 25 percent of books published in the United States today are acid-free and that this percentage is unlikely to change in the near future. Even if widespread use of acid-free paper occurred tomorrow, the problem remains of how to preserve the books and other papers that have already accumulated in libraries.

PRESERVATION TECHNIQUES

Libraries are no strangers to preservation. Over 40 institutions in the United States as well as the national libraries of many other countries are actively pursuing preservation programs, spending millions of dollars each year. Preservation involves a wide range of activities, including the individual conservation of important and rare books and documents, environmental control, microfilming, binding of books, and the training of staff in proper storage and handling procedures.

There are two general approaches for handling materials that have become too brittle to use—transfer to another format and strengthening. Transfer techniques include microfilm, optical disks, and magnetic tapes. Microfilming is the only one in common use today and is usually considered relatively high cost. These alternatives are beyond the scope of this study and were not reviewed.

Strengthening treatments to prevent paper from crumbling include the traditional approaches of laminating or mounting embrittled paper that are performed one page at a time and new techniques that are under development to reconstruct the long chain molecules that give strength to paper. This latter technique, using polymerization in the paper, essentially strengthens the cellulose fibers by forming physical links between the broken cellulose fibers, restoring the paper's flexibility. However, this may be a short-term solution for acidic papers unless deacidification is also part of the treatment.

There is one combined strengthening/deacidification process that is operating (at a very small scale) and at least two are under development. The Austrian National Library has a small-scale system to treat its newspaper collection using an aqueous

How the Library of Congress Obtains Materials

1. *Copyright Office* receives about 130,000 books, 230,000 periodicals, and tens of thousands of sheets of music each year. It also receives maps, motion pictures, telephone directories, phonograph records, computer tapes, ballet notations, etc. All of these materials are received free of charge.
2. *Government Exchange* provides records of affairs from Federal, State, major cities, and foreign governments, as well as international government organizations. About 4 million publications are obtained through these channels each year. None of these materials are purchased. The Library obtains non-Federal materials by trading Federal publications.
3. *Gifts* include personal papers given outright or deposited with the Library. In 1980, about 1.8 million pieces were received.
4. *Purchased Materials* include:
   - newspapers—330 U.S. and 1,000 foreign;
   - foreign magazines—about 30,000;
   - foreign books—includes significant nonfiction and representative literature;
   - research materials for the CRS Library; and
   - blind and physically handicapped collection, this is the largest portion of the purchase budget, in 1980, about 1.9 million volumes were purchased for about $35 million.

SOURCE: Charles A. Goodrum and Helen W. Dalrymple, *The Library of Congress* (Boulder, CO: Westview Press, 1982), p. 337.

process with calcium hydroxide for deacidification and methyl cellulose for strengthening. The German Library in Leipzig is developing a different strengthening process using this same aqueous deacidification chemistry. Strengthening will be accomplished by depositing a new layer of paper composed of cotton cellulose fibers. The British Library has begun development of a polymerization process for strengthening. Depending on the chemical used, the process could also be used to deacidify. None of these combined processes has been developed far enough to be considered for mass preservation in the immediate future. Some manufacturers engaged in other businesses believe that their equipment can be adapted to deacidification processes. No data are available to substantiate this claim.

For materials that have not yet become brittle, deacidification techniques have been developed to neutralize the acids that cause the paper to deteriorate and to deposit an alkaline buffer that acts as a reserve to neutralize any acids that may continue to form. The effect is to extend the life remaining in the paper at the time it is treated.

Most of the deacidification techniques in use today are manual, small-scale, liquid solution processes. Sheets of paper are either dipped in or sprayed with a solution containing one or more alkaline compounds. These compounds neutralize the existing acids and some excess material is deposited in the same paper as a buffer. The alkaline compounds are normally magnesium or calcium carbonates and the solvents can be aqueous or non-aqueous.

Current manual techniques are time-consuming and expensive. The paper must be treated one page at a time. Books must be unbound if they are dipped into the solution. Each page must be tested to make sure that inks, colors, etc., are compatible with the solvents being used. (Some solvents not only dissolve the alkaline compounds used to neutralize the acids but will also dissolve certain inks and pigments and other book materials.) These processes are painstaking operations and demand highly skilled practitioners. They are normally used only for rare books where the value of maintaining the original format is greater than the cost of treatment. These small-scale preservation processes

Photo credit: Library of Congress

Manual book deacidification technique treats one page at a time

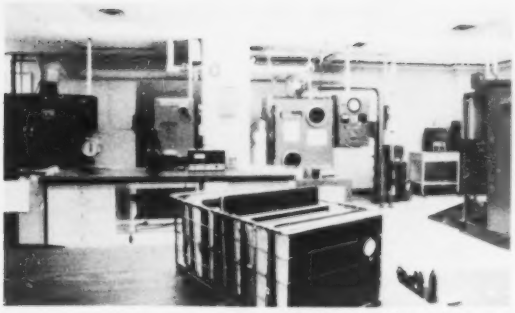


Photo credit: Library of Congress

Wei T'o deacidification plant at the Canadian National Library

are too costly and too limited in capability to effectively solve the massive, general problem of acid deterioration. Spray deacidification offers improvements over dipping but still is slow and requires pretesting.

Major libraries around the world have expressed the need for a cost-effective mass process to treat acidic deteriorating paper in their collections of millions of books, maps, manuscripts, and other valuable documents. Many have experimented with chemical processes to deacidify books and thereby extend the life of the books. There are a few processes that show some promise for use in mass deacidification schemes. More data are available on the DEZ process developed by the Library than on any other process, and it appears to be the most sophisticated. Nonetheless, a few other processes appear to have some potential merit for mass deacidification. For example, two have operating systems routinely deacidifying more than 10,000 books per year. One system (developed by Wei T'o Associates) has been operating in Canada for over 7 years, treating about 40,000 books per year; and the second of a slightly larger capacity has just begun operation in France. Both are liquid, nonaqueous processes.

Libraries in the United States have not invested in any mass deacidification system to date but many have looked to the Library of Congress to provide leadership in determining the most effective process and in developing a feasible system.

THE LIBRARY OF CONGRESS' MASS DEACIDIFICATION PROGRAM

The acid paper and book problem is of huge proportions at the Library of Congress. As a major part of its overall preservation effort, the Library initiated a program aimed at deacidifying books and other paper formats en masse. Much of that program has been devoted to the development of a process capable of treating at least 1 million books per year. The process chosen by the Library is unique and has many advantages over more traditional techniques. It does not damage inks, colors, and other book materials usually affected by liquid processes; and closed volumes in large quantities can be treated together with little or no preselection or preparatory work.

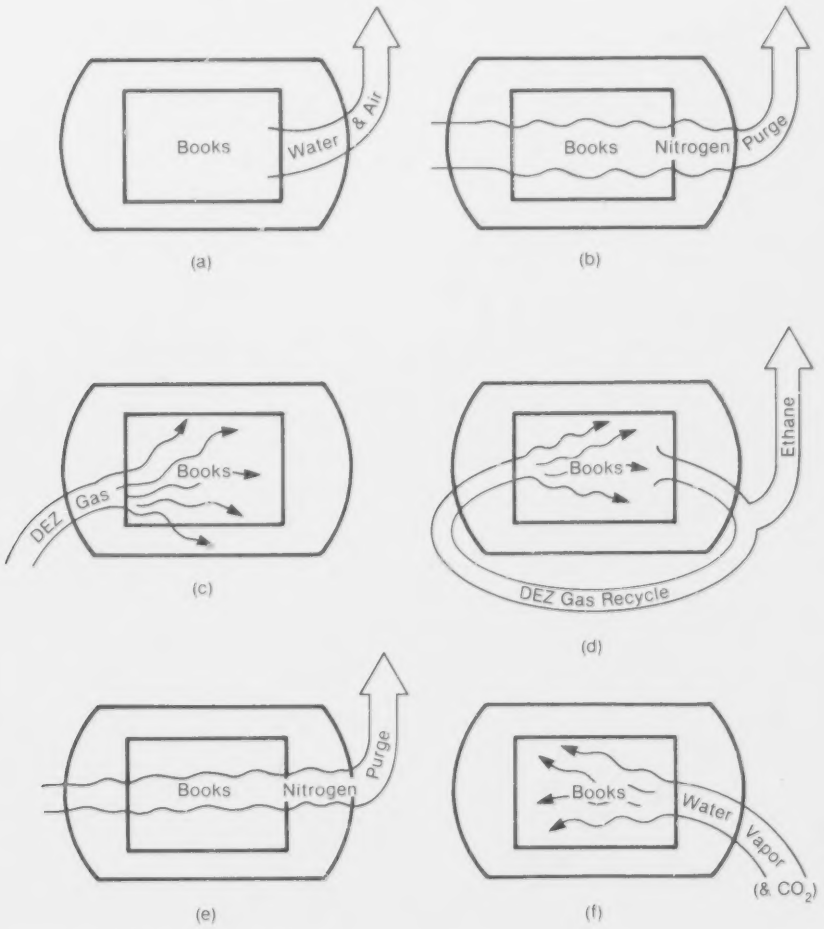
How the Library of Congress Selects Materials

- About 10 million items are received by the Library each year, of these about 1.5 million items are selected for inclusion in its collections.
- Selection policies are based on subject matter, four levels of retention (i.e., comprehensive, research, reference, minimal), specific decisions about a subject and specific decisions about individual items.
- Routine selection involves review by about 30 specialists. About 30 other people are involved in processing the book and getting it onto the shelves.
- Most domestic books are obtained through the Copyright Office. The Library retains the majority of hardback books, a sampling of paperbacks, and many college textbooks. Almost no texts for elementary or high school are retained.
- Most foreign books are selected after purchasing the same publications as the largest library in the country or by working with a single dealer in a particular country.

The Library began to develop a mass deacidification program in 1973. Most of the effort to date has focused on process development. The Library's chemists explored various ideas in mass deacidification and invented a process using diethylzinc (DEZ) vapors to treat the books. DEZ belongs to a class of chemicals called "metal alkyls" or "organo-metallics." Metal alkyls, in general, and DEZ in particular, will react very quickly with acids and other similar compounds. Deacidification occurs as DEZ vapors permeate the books and react with all acids in the paper converting them to neutral or alkaline zinc salts. DEZ vapors can permeate closed books rapidly and completely, thus the process can take place on many volumes stacked reasonably close together.

DEZ vapors also react with water in the paper to form zinc oxide. The zinc oxide remains in the paper and acts as an alkaline buffer that can neutralize acids that may form after treatment. The amount of zinc oxide deposited on the paper de-

Key Steps in the DEZ Treatment Process



SOURCE: Office of Technology Assessment, 1988

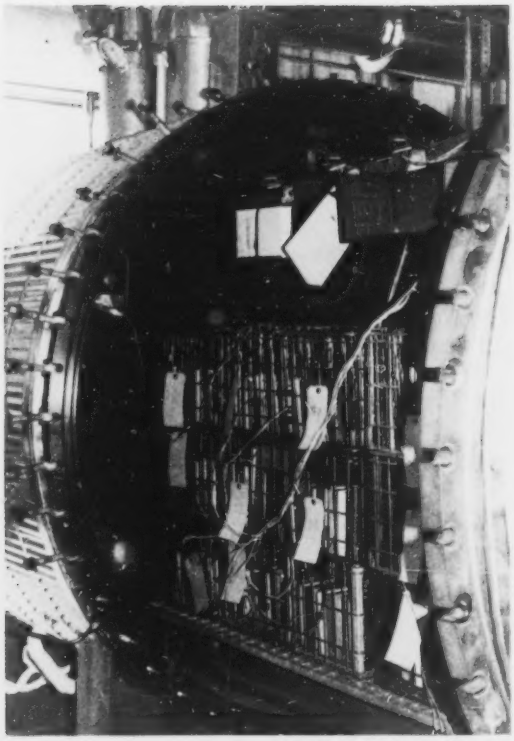


Photo credit: Library of Congress

The book treatment chamber at the Texas Alkyls DEZ pilot plant

pends in a large part on the amount of water in the books at the time of treatment. It also depends on the amount of the DEZ used, time of exposure, and particular permeability of the paper.

The DEZ process basically consists of three steps: dehydration, permeation, and rehydration. Dehydration reduces the amount of water in the books to an amount based on how much zinc oxide is desired to be deposited in the books. Permeation exposes the books to the DEZ vapors, neutralizes the acids present, and deposits zinc oxide. Rehydration restores moisture to the books so they can be handled in a normal manner.

Metal alkyls, including DEZ, are pyrophoric, meaning they will spontaneously ignite if they come in contact with air. Therefore, the book treatment process takes place in an air-free environment at very low pressures within a vacuum chamber. Strict

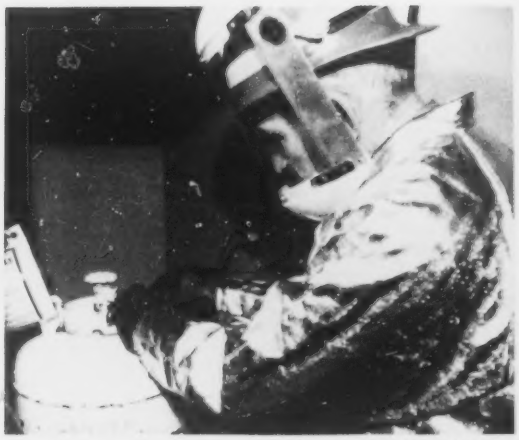


Photo credit: Library of Congress

Hooking up a DEZ cylinder for a book deacidification test

safety practices must be followed to avoid the risk of fire.

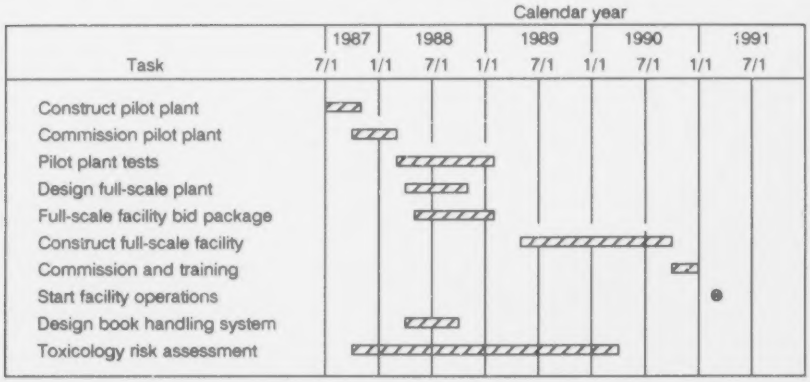
Numerous laboratory and large-scale tests have been conducted to verify and develop the process. Currently, a pilot-scale system (capable of treating 300 books at a time two to three times per week) has been designed and constructed at Texas Alkyls, Inc. outside Houston. Texas Alkyls is the principal manufacturer of diethylzinc in the United States and has been working with the Library since the beginning of its program.

This is actually the second pilot plant that has been built by the Library. The first was designed, built, and operated by Northrup Services, Inc., on site at NASA's Goddard Flight Center in Greenbelt, Maryland. This plant was demolished in 1986 after two fires and an explosion rendered it inoperative.

Construction of the Texas Alkyls pilot plant was completed in October 1987. The first tests of the plant began in December 1987. The Library has contracted with Texas Alkyls to run a series of tests during 1988. These tests will evaluate the system's operability, effectiveness of treatment, safety, and economics. They will also be used to optimize the process parameters, cycle times, and final design (including plant capacity) for a full-scale system.

The full-scale plant is scheduled to begin construction in 1989 and to begin operation in 1990-

Library of Congress, Mass Deacidification Program: Current Schedule of Major Tasks, January 1988



SOURCE: Office of Technology Assessment, 1988, based on information received from Library of Congress

91. The plans for who will design, construct, manage, and operate the plant have not yet been determined. The Library has given considerable attention to locating the plant at Fort Detrick in Frederick, Maryland. If this site is chosen, the U.S. Army Corps of Engineers would contract for the design and management of the construction of the plant; and the Library would probably contract the management and operation of the plant to a private chemical company.

FINDINGS

The Library Process and Program

The Library of Congress has recognized the problem of acid deterioration of books and other paper materials for a long time. The Library staff have invested considerable effort in the investigation of deacidification processes and have selected the DEZ process as the one that meets their needs. Selection of the DEZ process by the Library of Congress has followed a logical procedure comparing alternatives on the basis of criteria established by the Library for its collection. **Since the late 1970s decision to pursue the diethylzinc (DEZ) process, most of the Library's effort has been devoted to perfecting this process and solving the engineering, safety, and other problems associated with the chemical treatment plant.**

The Library of Congress has built a second DEZ pilot plant and has begun a series of engineering and process effectiveness experiments as of this writing. The Library staff have done early planning but have not made firm decisions yet about the management, design, construction, and operation of a full-scale facility. A total system including book selection, handling, and transportation is planned, but has yet to be designed. Final plans for contracting and management of the full-scale plant also are needed. **The Library of Congress needs to consider important details of project planning and management soon in order to more accurately predict costs, capacity, and operational results of this major undertaking.**

Technological Effectiveness

The DEZ process developed by the Library of Congress extends the life remaining in the paper at the time it is treated. The Library claims that the process will extend the life of acid book paper three to five times its life if left untreated. These claims are based on fold endurance tests that have been made on a variety of test papers. **But it is not**

clear how long the life of an actual book in the Library's collection will be extended.

The Library intends, as part of its current pilot-plant tests, to analyze the overall benefits to all books to be expected with DEZ treatment. **The results of those tests are needed to quantitatively project the benefits of the entire program.** Some scientists would also urge more tests on older papers typical of the Library's collection.

Although fold endurance comparisons have been traditionally accepted by the book preservation community, some paper chemists believe that it is not the best way to measure effectiveness of deacidification processes and that it is not easily correlated to fiber breakdown. Folding is meant to simulate a physical failure mechanism, but the principal failure mechanism of brittle paper is the chemical breakup of the cellulose chains. **Therefore, either a better physical measurement or more direct chemical measurement such as a comparison of the degree of polymerization over time may lead to a more convincing measure of permanence.**

Neither the DEZ process nor other deacidification techniques will make brittle books usable. Whether or not books and papers are deacidified, those that are already too brittle to use will require a strengthening treatment to prevent the paper from crumbling. The Library is working toward development of a strengthening process that could be used in conjunction with the DEZ facility but it has not yet established firm plans for an acceptable process.

Safety

DEZ is a hazardous substance that must be handled carefully and in accordance with strict safety procedures. As previously discussed, DEZ will spontaneously ignite if exposed to air. Fire is the principal hazard, and there is a remote chance of explosion. **However, DEZ has been used safely for other purposes.** There is no unusual fire hazard, however, once the books are treated.

The early engineering development of the DEZ process by the Library and NASA Goddard resulted in an accident caused by inadequate management of engineering and safety procedures. Careful attention to safety and good chemical process engineering standards have been followed with the design, construction, and plans for operation of a second pilot plant with Texas Alkyls in Houston. **OTA finds these initial efforts adequate, but pilot plant tests now underway are needed to demonstrate all safety aspects. As of this writing a series of engineering experiments is underway at the Houston pilot plant.**

The full-scale plant, if built, will need equal or greater engineering attention, especially related to safety standards and practices during operations. Scale-up design will encounter additional engineering problems. Safety practices must be developed for a new site, new plant management, new operators, and a new community setting.

OTA has qualitatively assessed the risks of a full-scale DEZ plant and concludes that the greatest risk is damage to the plant itself. The risk to plant workers is greatest during initial hookup of the DEZ storage tank, when performing maintenance, or when fire-fighting. **OTA also believes that safety concerns associated with transportation of DEZ to the full-scale plant should be more thoroughly analyzed.** The Library must also take extra precautions to work with the community where the plant is located in identifying and minimizing risks.

Health and Environmental Impact

There is little evidence to date to suggest that the DEZ process poses any unusual risk to public health or the environment. A review of the literature, however, reveals a lack of data on the impacts of chronic inhalation of zinc oxide powder, which may be present as small amounts of dust when treated books are in use. The Library has chosen to conduct a full-scale risk assessment, including chronic inhalation animal studies. There is some debate about the Library's responsibility to conduct such a full-scale assessment. The Library feels that it may be held responsible for future health problems of Library workers and users and plans to proceed with the study. Some others feel that the Library may spend too much time and money without being able to come to any reliable conclusions. The study will not be finished until construction of the full-scale plant is planned to start. Some believe that a single study seldom provides conclusive evidence. Advocates of this latter position feel that a thorough literature review and a quantitative exposure study (now part of the full-risk assess-

ment) are enough to fulfill the Library's responsibility.

A preliminary environmental assessment was conducted on an earlier full-scale design. The assessment concluded that the process posed no environmental risks. However, the only location considered was Fort Detrick and safety details were not discussed. **A more extensive Environmental Impact Statement for the full-scale facility will probably be necessary.**

Cost

To accurately and completely define costs, capacity, and operations for a full-scale DEZ facility, some basic decisions and plans remain to be made. These plans include a total system design, including not only the full-scale DEZ facility but also the procedures for book selection, handling and transportation, and final plans for contracting and management.

For the purpose of this OTA study, the Library of Congress estimated the capital cost of the full-scale DEZ deacidification facility at $4.9 million without a contingency and the annual operating costs for a capacity of 1 million books per year at $1.8 million. These costs do not include a number of items that have not yet been detailed enough to make estimates (e.g., book transportation) or are not considered now by the Library to be applicable (e.g., engineering development at the pilot plant). **OTA considers that actual costs could vary considerably from these estimates once the important engineering and planning decisions listed above have been made.** OTA also believes it useful to add rough estimates of the missing items and contingencies for unknown factors and thus arrive at a more inclusive budgetary estimate.

The most critical factor in per-book costs is the capacity of the final plant. The vacuum chamber cycle time has a major influence on capacity as do transportation and book handling factors. These latter parts of the system need to be defined. Costs for transportation and handling are also very rough at this time. OTA has attempted to factor in these uncertainties to arrive at its own estimate. OTA has also used a ±20 percent range of numbers because of the uncertainty of these costs. OTA's resulting *per book cost estimate is from $3.50 to $5.00* including amortization and interest on capital assuming a 1 million books per year plant capacity.

Alternative Processes

Although the problem of deteriorating paper has been known for almost 100 years, **only one mass deacidification plant has been operating anywhere for any length of time.** The Wei T'o process has been used by the National Archives of Canada for

Comparison of Alternative Mass Deacidification Processes, As of January 1988

Criteria	Ideal	DEZ[a]	Wei T'o	Bookkeeper[b]
Preselection of books	No	No	Yes	Minimal[c]
Predrying	None	Yes	Yes	None
Impregnation time	Short	Long	Short	Short
Treatment plant	Simple	Complex	Less complex	Simple
Effect on inks and colors	None	None	Some	Minimal [c]
Effect on plastic covers	No	No	Yes	Minimal[c]
Neutralization	Complete	Complete	Needs verification[d]	Needs verification[d]
pH of treated paper	7.0-8.5	7.0-7.5	8.5-9.5[d]	8.0-9.0[d] (surface)
Alkaline reserve	About 2%	1.5-2.0%	0.7-0.8%[d]	2%[d]
Danger to health	None	Risk of fire	Uncertain[e]	Uncertain[e]
Impact on environment	None	Low	Uncertain[f]	Uncertain[f]
Stage of development	—	Operating pilot plant (2 mo.)	Operating pilot plant (7 years)	Lab tested pilot design
Cost	—	Moderate to high[g]	Low to moderate[g]	Low[g]

[a]Library of Congress' DEZ process.
[b]"Bookkeeper" submicron particle process.
[c]Based on telephone conversation with Dr. J.J. Kozak of Koppers (Nov. 2, 1987). No independent assessment.
[d]No formal independent analyses have been made. Manufacturer's data indicates complete neutralization under laboratory conditions.
[e]Initial indications are good but no formal assessments have been made.
[f]Some concern about the future regulation of fluorocarbons used in these processes.
[g]Based on OTA analysis and extrapolation of limited cost data furnished by developer of each system.

SOURCE: David Hon, "An Evaluation of Mass Deacidification Processes for Book Preservation and a Comparison of Their Chemical Characteristics and Effectiveness," prepared for OTA, November 1987; updated by OTA.

the past 7 years at a capacity of about 40,000 books per year. There are no deacidification facilities that can handle the large number of books (over 1 million books per year) envisioned for the Library facility. Other systems are in operation at a much smaller scale, are designed for a pilot plant scale, or are only ready for testing on a pilot plant scale.

The Library selected the DEZ process carefully. Alternatives were compared against criteria established by the Library for its collection. However, since the decision to pursue the DEZ process was made, **very little work has been done by the Library to encourage the development of other, emerging technologies.**

Of those processes for which OTA had sufficient data, two of them, Bookkeeper and Wei T'o, merit some consideration as alternatives to DEZ. Table 2 compares some relative criteria of DEZ and these two alternatives.

In general, the effectiveness of deacidification processes has not been unambiguously established. OTA has found no independent tests and evaluations of the Wei T'o and Bookkeeper processes. All data on treatment results have been developed by the firm or organization that is promoting the process. This is also true of the Library of Congress. (However, the Library of Congress' Laboratory is highly regarded as a leader in the field and tests of DEZ treatment effectiveness are far more extensive than those conducted on the alternative processes.) **Without some independent tests with standard procedures, comparisons of the final results of alternative processes will always be uncertain.**

By comparision to Bookkeeper and Wei-T'o, on a pilot plant scale (50 to 150 books per day), the Library of Congress' pilot plant at Texas Alkyls appears to be considerably more expensive. **Whether the cost difference would be significant for a larger scale cannot be determined without further pilot plant tests (not yet done at all for Bookkeeper) and complete design for the large-scale plant (needed for all three systems).**

OPTIONS

The Library of Congress has developed a unique and effective process, using diethylzinc (DEZ), that is suitable for the mass deacidification of its collection, and it has a credible pilot plant program using that process currently underway. This OTA technical review of the DEZ process and the Library's accompanying development program indicates that if carried to completion it has a high potential for meeting the Library's stated goals.

However, the overall program is still in the developmental stage with difficult and complex tasks ahead. Additional work is needed to determine accurate costs for full scale operation (including the deacidification plant itself, transportation and handling of the books, and associated activities at the Library) and how such an operation would be managed. Also, the apparent competition among several firms and institutions for the best deacidification process would make continued evaluation of the relative costs and effectiveness of alternate deacidification processes prudent.

OTA's analysis concludes that it would be useful to consider a range of approaches that would address these uncertainties. Some could be adjuncts to the Library's present program; others may require changes to the existing program and possibly delays in present schedules. While these approaches were developed by OTA in conjunction with its Advisory Panel for this project, some may also reflect the present thinking of the Library staff as well. They are presented as options because, to the best of OTA's knowledge, they represent a departure from present, documented plans for the program.

Option To Contract for Complete Book Treatment Service

The Library's mass deacidification program is a major undertaking that will require significant management attention over a long period of time. The Library of Congress has significant expertise

in paper preservation and the research and testing aspects of mass deacidification. However, the Library lacks staff and expertise in those areas (e.g., chemical plant design and operations) that will require the greatest focus as the project moves from pilot plant testing to production plant construction and operations. If the Library takes on substantial engineering and management responsibility for a full-scale plant, it will certainly require a careful evaluation of staff and organization to assure the proper level of expertise and a sufficient size of staff to meet scheduled dates. (If the Library works with the Army Corps of Engineers to build the full-scale DEZ plant at Fort Detrick, its staff would need to be evaluated in cooperation with the Corps of Engineers.) An alternative to this approach, however, is to fashion a contracting arrangement with a private firm that would relieve the Library of the need to go much beyond its own field of expertise.

It may be beneficial for the Library of Congress to seek a private contractor to furnish all aspects of management, construction, and operations for a full-scale deacidification facility. The contractor could furnish the site, construct the entire plant, transport the books and all supplies and guarantee to treat each book in accordance with specifications supplied by the Library. If the DEZ process is selected, the Library could license it to the contractor. The contractor could furnish this service at a fixed price per book or per year.

In order to follow this option the Library would need to prepare a comprehensive bid package to assure that a contractor would meet cost and performance criteria. Specific provisions would be needed for operating the treatment process, for pickup and delivery of books, for guaranteeing production quantity and quality, and for Library oversight.

By contracting with a private firm to provide complete services for deacidification at a fixed price per volume, the Library could limit its role, as it has done with the DEZ pilot plant, while leaving the management and operations of the facility to a firm with expertise to handle engineering and safety complexities. This approach would also minimize the number of government parties involved in the facility (including elimination of involvement by Fort Detrick personnel and the Corps of Engineers). Additional benefits of this approach include defining the actual costs of full-scale plant construction and operation by requiring detailed prices in each bid. It would also make it easier for the facility to treat materials for other libraries, as capacity allows. Also, with this approach, the Library would not need to build up its management and engineering staff but could concentrate on quality control and further research. A possible disadvantage of this option would be a reduced flexibility to modify and possibly improve the process in the production phase.

Option To Support Development of Alternative Processes

Even though the Library of Congress has made an effort to keep informed of the range of other work on deacidification processes both in the United States and abroad, the present situation gives the impression of competition among several firms and institutions for the best process. In fact, some scientists have criticized the Library for promoting its own process too forcibly in the popular literature rather than publishing in scientific journals subject to peer review. In the United States, at least two private firms could possibly offer a deacidification service to the Library and other libraries if some funding were available for further development and testing.

It may therefore be useful to support some alternative deacidification processes in an effort to more accurately define the costs and benefits of those processes. The Library of Congress could sponsor private competition to build and test one or more pilot plants based on a minimum set of criteria for treatment of books. This would require establishing an acceptable proof of treatment effectiveness and a procedure for submitting such proof. It would require funding a portion of one or more test programs. If the results are to be used by the Library in its path to a full-scale plant, it might also result in a delay or interruption of the present DEZ plant development.

The advantage of this option would be to determine more accurately the relative costs and benefits of alternative mass deacidification techniques. Most indications, at present, are that the available

alternatives are less effective in mass treatment than DEZ but also are less costly. This conclusion, however, is based on insufficient data. In addition, there may be some portion of the Library collection and a portion of many other libraries' collections that could be effectively treated by a lower-cost process if it were available.

Option To Support Independent Evaluation of Deacidification Processes

OTA's analysis concludes that insufficient data are available on the effectiveness of alternative deacidification processes to evaluate their benefits to library collections. An independent laboratory test program could provide these data. It may also provide valuable data for other libraries to evaluate costs and benefits to their collections.

Comparative tests could be run with a number of processes that appear to have merit either for the Library of Congress or other libraries to evaluate the effectiveness of these different processes. A testing program would require standardized testing of the effects of treatment on the chemical properties and components of paper; the effect of treatment on mechanical and optical properties of paper; and the stability of treated papers to light, pollution, and other degradation mechanisms. Such a testing program could be conducted by an independent body, to avoid any perceived conflict of interest. The National Bureau of Standards or other competent agency could be used to oversee the testing program. Although a comparative testing program may not conclusively demonstrate the superiority of a single process, it would at least ensure that comparative information on all relevant paper properties was available to decisionmakers.

Option To Optimize Deacidification Strategies

OTA concludes that deacidification of the Library's present and future book collection is a formidable task and that further examination of strategies could lead to simplification of that task.

The Library of Congress could seek to optimize more rigorously its strategy for deacidifying its collection. The current strategy for deacidification planned by the Library is to treat all incoming books first, with a minimum of preselection. This strategy affects the overall cost of treating the collection. It may be more cost-effective to identify books that are in greatest need of deacidification and treat them first, identify books that are on acid-free paper and not treat them, and use different deacidification processes for different portions of the collection. The Library looked into a more rigorous selection strategy in the past and concluded that it would be very difficult to do. However, as the costs and capabilities of alternative processes become better defined, it may be appropriate to do a more careful analysis of the costs and benefits of preselection.

As part of this option, it may also be worthwhile to determine ways to encourage the use of acid-free paper. The more books that are printed on acid-free paper, the fewer that would require deacidification. To accurately compare and optimize strategies, more information would be needed to be collected on trends in acid-free paper production, the make up of existing and future Library of Congress collections and the range of benefits from deacidification to be expected for the variety of books and papers in the collection.

NOTE: Copies of the report "Book Preservation Technologies" can be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402-9325, GPO stock No. 052-003-01103-4; $5.00.

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